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Design Strategy of a Compact Unglazed Solar Thermal Facade (STF) for Building Integration Based on BIM Concept

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Abstract

This paper discusses the specific design strategy of a novel compact unglazed Solar Thermal Facade (STF) for building performance research in architectural practice. It identifies the basic role of such STF in the building performance simulation and analysis. A dedicated design strategy based on the BIM (building information modelling) concept for application of the proposed STF is then developed in details. This research work clarifies the necessary steps in ensuring that the environmental/economic factors and energy-efficiency strategies of the STF are integrated with the building design and analysis process at the early stage.

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Keywords: Design strategy; Solar thermal facade; BIM;

1. Introduction

Energy demand in present world is growing continuously, and the buildings are responsible for the use of large amount of energy, which accounts for more than a third of the total energy supply [1]. Buildings are thus one of our potential opportunities for energy conservation and environment protection. With regards to building application, the utilization of renewable energy is, without a doubt, one of the most encouraging ecological avenues especially towards the sustainable and resilient city development. Solar

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energy, as a major renewable and eco-friendly energy source with the most prominent characteristic of inexhaustibility, is promising currently to offer potential solutions for sustainable development. Compared to solar photovoltaic systems, solar thermal technology exhibits great advantages of higher cost effectiveness with much shorter payback period, more mature and reliable domestic applied technology with massive production globally, and potential in large scale building application [2]. It has been forecasted that solar thermal technologies will experience a boom of a growing solar fraction demand in buildings with available applications of heating, cooling, hot water supply, or even power production [2]. Under this circumstance, a compact unglazed solar thermal façade (STF) is proposed as shown in Fig.1. The single-embossed metal structure engenders not only high heat transfer performance owing to finned absorbing surface and crossflow over the pin fins but also great feasibility in assembly of either parallel or series flow pattern [3]. The proposed STF could be made at the standard modular size to form up the building external decorator for both horizontal and vertical installation, which could be applied as either wall/roof or balcony external cover/claddings.

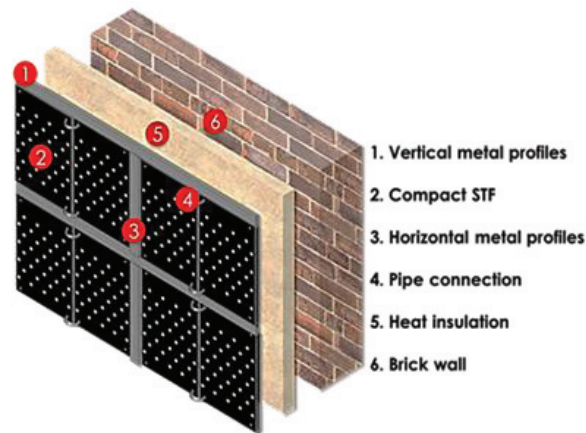


Fig. 1 Schematic of the compact unglazed STF integration

2. The role of STF in high performance building integration

Generally, there are three main methods for the high-performance building design, as the passive design strategies, the employment of advanced building technologies and the application of renewable energy systems [4]. Passive design strategies include factors of shading, response to building orientation, solar heat gain, natural ventilation, and daylight effect etc. Active design approaches include use of energy-efficient building systems and advanced building technologies where appropriate, such as mixed-mode ventilation, heating and cooling systems, hot water supply, and power systems. Renewable energy systems should be used to supplement energy demand with renewable sources. As a multi-function technology, STF can be employed as shading or rainscreen in the aspect of passive design strategy, an advanced building envelop to buffer the overall building energy load in the aspect of active building technology, as well as delivery of solar thermal as a renewable energy system. As a result, these characteristics endow the proposed STF as a subset of the three main methods that provides one of the most appropriate solutions for the high-performance building design.

3. Importance of building performance simulation and analysis

Because there are growing number of strategies/technologies involved in a single building project, building performance simulation is considered more indispensable during the design process. Building performance simulation as an integral part of the design process can help in: 1) understanding and investigating different options; 2) establishing metrics to measure improvements associated among different strategies/technologies; 3) maximizing real contribution; and 4) making design decision in achieving low and zero energy buildings, i.e. different passive/active design options or renewable energy systems [4].

As for the application of the STF technology, it requires solar exposed orientation, lower disturbed wind direction, collecting area, solar thermal demand and system size etc. Therefore it is more significant to carry out solar resources prediction, optimal design option and further improvement using modelling techniques. However, a disconnection between architecture design and environmental thinking normally exists, where green components like STF can be included as part of a strategy for high-performance buildings, but such informative knowledge is hard to be shared. Traditional design process starts from architects to engineers simply in one-way direction, leading to high levels of congenital design strategies, i.e. conventional air conditioning, double skin facades, extra thermal insulation layer or complex motorized shading systems etc. These design strategies often mask an underlying lack of basic environmental thinking and impede STF's widespread deployment. In order to understand the effects of dedicated STF on building performance, and enable the parallel architecture design proceeding, different cycles of building performance simulation and analysis should be involved as part of an integrated design process on the basis of current available simulation tools or platforms.

4. Design strategy of STF based on BIM concept

Typically, a traditional design method usually simplifies the design by assumptions from the rules-of-thumb, which could be inaccurate sometimes. It often cares more in aesthetic feature to design a STF without considering performance impacts or possibility of performance measurement and evaluation of a STF solution especially at the early design stage. These are mainly because of the limitations of conventional design and simulation tools which are not compatible with the working methods and needs of architects and designers, or the tools are judged as complex and cumbersome [5]. With the widespread of building information modelling, STF-BIM is proposed as one of best methods for integrating performance simulations of STF with the building design. BIM is the process of generating three-dimensional, digital representation of building data throughout its life cycle. It is an innovative technology for bridging communications between the architecture, engineering, and construction industries. Compared to tradition design method, the STF-BIM design strategy has an ability to estimate the impact of a STF decision across the whole process. The performance is simulated, analyzed, and predicted with reliable quantitative data through sufficient building and STF models, rather than simple assumptions from design experience. For example, analytic data from the STF-BIM analytical model could be a driver to parametrically control the geometry of STF elements in the design model, such as sun shades, orientation, or inclination angles etc. Such feature enables the high possibility for design professionals to produce the evaluation of multiple STF alternatives against different design priorities, like time, resources, energy, investment, and other valuable information, thus helping in the decision-making process towards sustainable design.

4.1 STF-BIM design procedures

The STF-BIM concept is composed with a three-element interlinkage with STF solution, STF-BIM design model and STF-BIM analytical model, all the elements can be penetrated into different design

stages. Fig. 2 illustrates that, as early as programming and conceptual stages the analysis may carry out the contextual aspects, such as climate information, STF orientation, STF colour/texture, STF size/shape and STF massing. Then at conceptual and schematic phases, the analysis observes the whole impact of STF to the building when it serves as different envelope components. In addition, an iterative cycle of different design options should be analyzed in terms of sun shading, overshadowing of surrounding buildings, thermal comfort, and daylighting etc. The decisions at these stages are of high impact on the design because they influence the exterior design character of the project, potential energy use reduction, and the comfort levels inside the spaces as well as the environmental and economic benefits. Finally, the STF array connection and the associated HVAC system together with the related cost should be highlighted mostly at design development and construction documentation phases. It is usually more important for designers to evaluate STF and building energy performance at the early project phases (programming, conceptual, schematic and design development), which prevents the project from drastic changes due to unsuitable energy and cost goals.

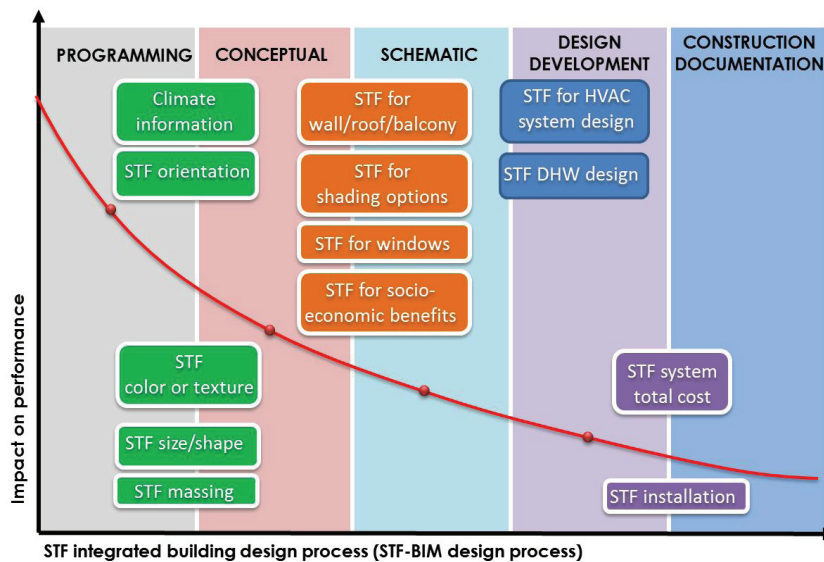


Fig. 2 STF design on building performance at different stages

Fig.3 follows to present the basic framework for incorporating building performance analysis procedures with the proposed STF. By initially defining energy target goals and setting up design criteria, the early design characteristics and decision could be explored, such as site, climate information, building orientation, shadow ranges, solar exposure, and daylighting etc. After then, the design solutions and optimizations are proposed and tested using more detailed three-dimensional building model for analysis of STF including aesthetical matching, components adaptability, and the associated solar exposure etc. Finally, the comprehensive energy and socio-economic simulation are conducted for the performance analysis of the STF incorporated three-dimensional building model, aiming to figure out the optimum design of the STF as well as the whole building energy systems. However, BIM design authoring software programs and analysis applications are currently distinct, and require the exchanges of data and building information [4]. To successfully employ STF-BIM models for energy performance and socio-economic analysis of building, it is important to consider the Level of Development (LOD), which refers to the amount of information embedded in BIM design models [4]. Fig.4 illustrates the relations of STF-BIM design process and analysis documentation, which recommends the LOD in STF-BIM design

models corresponding to each simulation analysis at different design stages. Inside, LOD 100 should include overall building massing, area, height, and volume. It can be applied to analyse building orientation, solar exposure and some passive initiatives. LOD 200 contains model elements as generalized systems or assemblies, and may include non-geometric information, such as material properties, cost etc., which can be used for performance analysis of shading devices, daylight analysis, basic energy analysis, thermal evaluation, and socio-economic assessment. LOD 300 consists of model elements that are more accurate in terms of quantity, colour, texture, size, shape, location, and orientation etc. It is considered for more detailed analysis done at LOD 200 in addition to the optimization of STF and its associated systems. It is important to note that these types of studies have the greatest impact on the building performance if they are conducted early in the design process [4].

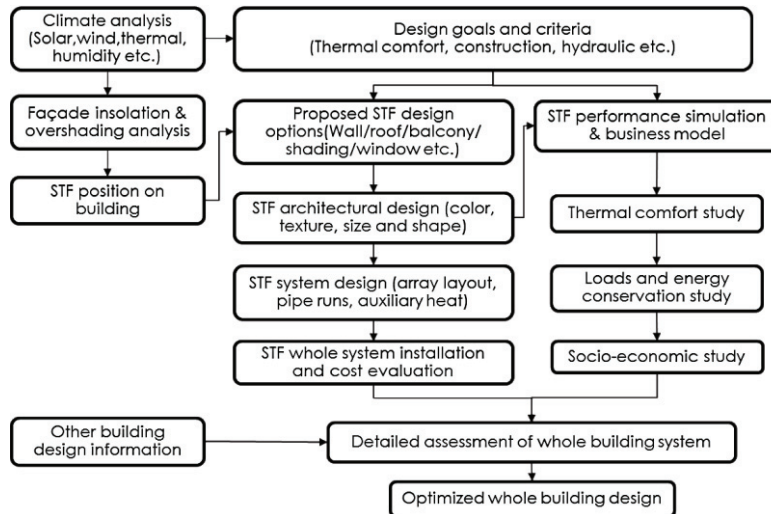


Fig. 3 Frameworks for incorporating building performance analysis procedures with STF design

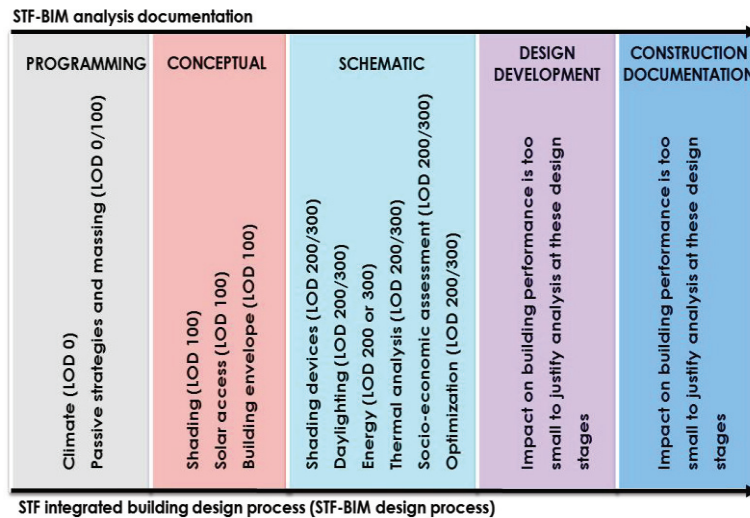


Fig. 4 Relations of STF-BIM design process and analysis documentation

4.2 Methods for information exchange between STF-BIM model and analysis application

Typical workflow and data exchange between STF-BIM design model and environmental analysis applications require the export of model information depending on the analysis objectives and the necessary information or LOD. For example, in order to determine the STF orientation that maximizes solar exposure on the facade, data exchange of basic LOD 100 through DXF file format is adequate for analysis. In terms of higher LOD 200 or LOD 300, data exchange can be performed through Green Building XML (gbXML) schema, a computer language specifically developed to facilitate transfer of building properties stored in BIM to analysis tools. In some cases, necessary modification of translated geometry or element properties may be required in the analysis software application.

However, importing the analysis results back into the STF-BIM design model and controlling the related geometric elements are still challenging. A custom-built plug-in for a typical BIM software - Revit platform has been recently developed that allows the import of analytical results, such as solar radiation into BIM design model. It enables importing of data through Excel spreadsheets and parametric control of Revit families based on the numeric values contained in the imported data.

5. Conclusions

The proposed STF is considered suitable for high-performance building design. One of best methods for integrating performance simulations of the STF with building design is STF-BIM concept. It could estimate the impact of a STF decision across the whole process, enabling the high possibility for design professionals to produce the evaluation of multiple STF alternatives against different design priorities for the decision-maker towards sustainable design goal. Within basic framework for incorporating building performance analysis, the STF-BIM analysis model need to be well managed and properly developed by considering the LOD and the required information necessary for performance analysis.

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Biography

Dr. Zhang is currently an Assistant Professor at the Department of Architecture and Built Environment, University of Nottingham, Ningbo, China. He has the multidisciplinary research experience in building physics, energy management and energy economics.